SP-STIM: Modulation of *in vitro* neuronal activity using RF-based waveforms

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Introduction

- The potential of **non-invasive brain neuromodulation** has sparked significant research efforts to propose technologies that can normalize brain activity impacted by neurological disorders.
- We propose to use **radiofrequency (RF)** waves with appropriate **modulation** to enable neuromodulation of specific activity patterns.
- Here, we used modulated **RF exposure** to investigate the potential neuromodulatory effects in an *in vitro* neuronal culture using a Multi-Electrode-Array (MEA).
- The choice of this approach should also bring us closer to a cellular-scale understanding of the **involved interaction mechanisms**.

Methods: Exposure system and neural cultures

- 7 rat-derived cultures of neuronal cells were exposed to a **30 dBm amplitude modulated (AM) radio frequency (RF)** electromagnetic fields.

- Performed using a transverse electromagnetic (**TEM**) cell and placed in an incubator to keep the culture at **37 degrees celsius.**

- MEAs had **60 available channels** to record the activity.

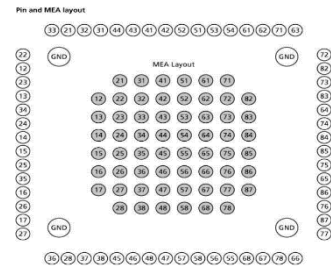- **15 min** periods of SHAM − RF − SHAM − AM RF − SHAM .

Data processing

- Data processing using *spikeinterface python package* for reproducibility.

- Bandpass filtering between 300-4500 Hz to **isolate spikes** (high-frequency component of recorded signals).

- No further processing of low-frequency activity was performed (focus on the timing of spikes and their temporal correlation with the stimulus).

- **Spike detection** performed using the Precision Timing Spike Detection algorithm [Maccione, 2009].

- **Autocorrelogram** calculation for visualization (i.e., aiming to identify peaks at latencies dt=1/f where f is the AM modulation frequency), in order to identify effects of **phase entrainment** of the AM-RF exposure signal on neuronal activity as quantified by the detected spikes.

Results

Theoretical possibility **of non-invasive RF neuromodulation** (novelty).

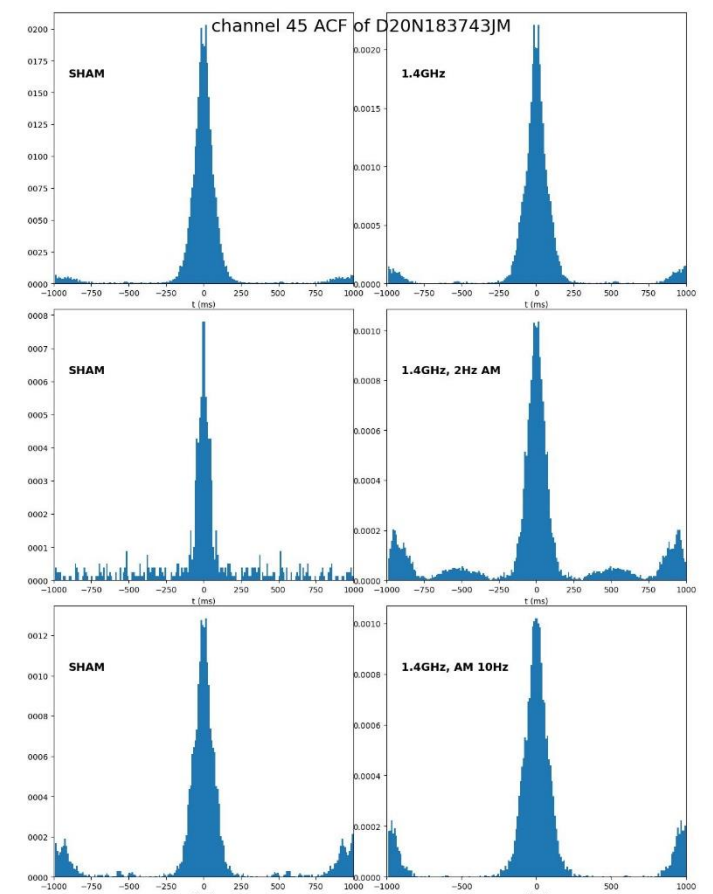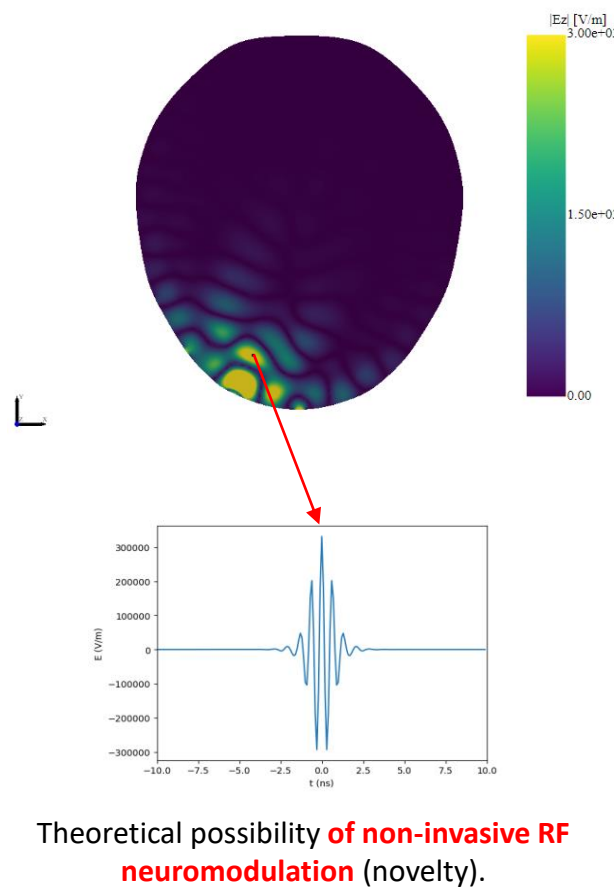➔ AM RF can exert **neuromodulatory effects**.

Conclusions

- We have conducted experimental recordings of the impact of **modulated RF** waveforms on the electrophysiological activity of **7 neuronal cultures.**

- The effect of heating was studied and kept minimal (**<0.5 degrees**) to avoid thermal effects on neuronal activity.

- First results demonstrate the **possibility to modulate activity with AM-RF**.

What's next ?

- Check results **reproducibility**.

- Comparison with **other spike sorting algorithms**.

- Testing for statistical difference between SHAM-RF and AM-RF using appropriate metrics (to be determined).

- Patent application on the waveforms and the exposure system/Publication of the final results.

References

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- Gaugain, G., Modolo, J. and Nikolayev, D. (2022) 'Temporal interference modeling error using purely conductive medium appoximation', in *2022 44th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* Glasgow: IEEE.
- Gaugain, G., Al Harrach M., Yochum M., Modolo J., and Nikolayev D., Phase entrainment of cortical cell types during tACS: a modeling study. *J Neural Eng, in press, 2024.*